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General Report — Session XIV: Northridge Earthquake, January 17, 1994

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General Report - Session XIV
Northridge Earthquake, January 17, 1994

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INTRODUCTION

Session XIV - Northridge Earthquake, January 17, 1994, included the submission of nine papers of high quality. The Northridge, California event (M_W=6.7) was a real world laboratory for evaluation of seismic impacts after the 1971 San Fernando Earthquake (M_W=6.6). The large increase in strong-motion seismographs (since the early 1970's) allows the closer evaluation of surficial, ground motion. The state-of-the-art for earthquake hazard evaluation and geotechnical design to resist seismic loads has advanced significantly in that score of years.

The Northridge Earthquake will offer significant new contributions for plate-margin attenuation, ground-motion amplification, and localized contributions to seismic hazards above blind-thrust faults. The seismicity and ground motion generation for this complex region is not directly applicable to other regions, where large ground-surface areas do not reside on the lurching fault.

The papers of Session XIV may easily be divided into three categories: Ground Motion, Project Performance, and Seismic Hazard.

- Ground Motion

Four papers advanced topics individually evaluating ground motion due to the Northridge Event. Each paper takes a somewhat varied approach to site impacts. A topic of considerable concern is the variation of subsurface conditions. In many strong-motion locations the depth to firm rock and the engineering characteristics of the soil horizons are not well established. The deep basin has several geologic peculiarities that simultaneously make the region: tectonically activity, geologically varied with very deep soil sequences, and geotechnically difficult to characterize and design.

- Project Performance

Four authors provide papers on class-specific projects. Each of the four papers enumerate two to twenty-two sites for the class of systems that are assessed. The determination of proper, seismic-resistant design is as the failures under seismic loading due to design technique or construction practice. The development of failure modes for some structures and the alternate citation of projects, that did not have those problems, advances the design of future structures beyond the mere observation of seismically-induced failures.

- Seismic Hazard

One paper appraises the recently-accepted risk of ***blind-thrust faults***, that produce a low-probability, great-hazard potential (as compared to other fault systems) in the Los Angeles basin. This threat needs scientific review and geotechnical/structural design improvements for new structures. This clarion call for the **existing** risk will aid the initiation of seismicity and design modifications.

GROUND MOTION

Yegian et al. (paper 14.01) provided an evaluation of many geotechnical-failure modes as related to ground motion due to the Northridge Earthquake. The authors provided discussions of apparent soil amplification and soil-structure interaction. Anecdotal evidence is cited for these two important features of the subject event. At similar distances a wide variation of peak accelerations were found. Topographic effects were also included. The ratio of peak base acceleration to peak free-field acceleration was used to suggest soil-structure interaction.

Manifestations of liquefaction, slope failures and rock falls, and ground deformations were provided. The "survey" of the damage region by *Yegian et al.* recommended that on-going research "will shed light" on "the causes and mechanisms of the related phenomena."

Celebi (paper 14.06) addressed the "Unique Ground Motions." *Celebi* cited the Northridge event for: 1. the largest number (250) of strong-motion records from a temblor; 2. very high, peak accelerations relative to comparable magnitude events; 3. near-field motions with long-duration, high-energy pulses; and, 4. significant site effects. The peak accelerations were found to uniformly exceed most attenuation relationships.

The severe damage to the Olive View Hospital was attributed to long-duration pulses. This motion produces large velocities and transmit large percentages of the energy to the structure. A temporary array confirmed topographic amplification of ground motion at a hill in Tarzana, Calif. Some recorded motions have 5%-damped, normalized response spectra that significantly exceed UBC Spectra for S1, S2 and S3 site conditions.

Davis and Bardet (paper 14.09) contributed the evaluation of the ground motions, tectonic displacements and deformations at the Van Norman water facilities. The site of 1.3 by 3.0 km area had eighteen seismographs, which ranged from 10 to 13 km from the epicenter. Peak horizontal accelerations varied widely with a maximum of 0.98 g. Some long-period pulses produced high velocities to a maximum of 177 cm/sec.

Permanent tectonic displacement from the thrust fault ranged from 16 to 24 cm eastwardly and 15 to 30 cm vertically. Ground deformation and liquefaction-induced lateral spreading occurred in the Lower and Upper Dam embankments, dikes, and compacted fill. Pipes and channels were severed. *Davis and Bardet* presented a case for greatly varying, near-field ground motions and corresponding site failures.

Chang et al. (paper 14.10) presented a very useful paper elaborating the variation in regional ground motion and compared the findings to attenuation and spectra relationships. A contour map of peak, horizontal acceleration is provided with a projection of the fault rupture plane and its epicenter, although soil and rock sites are contoured jointly.

Chang et al. suggested that three attenuation models accommodate the acceleration data. Calculated response spectra "often exceeded" the 1994 UBC design spectra in the epicentral region, while the spectra shape seem to match. Earthquake hazard maps may be improved with the consideration of soil conditions and topographic amplification, besides potentially liquefiable deposits and rock slide hazards.

PROJECT PERFORMANCE

Augello et al. (paper 14.04) reviewed the performance of 22 landfills under the loading of the Northridge event. The authors correctly cited the requirement to design solid-waste landfills to resist earthquakes without the benefit of case histories. No landfills suffered major damage. Only one landfill, Chiquita Canyon, was noted for significant damage that occurred to the soil cover and tears of the geosynthetic liner. Six landfills had moderate damage, while the remaining fifteen had minor to no damage.

Augello et al. recognized five modes of failure leading to cracking. "Brittle cracking of the stiffer soil veneer overlying ductile waste fill" was specified as the most significant cause. Downslope movement, breaks in gas extraction pipes, and loss of gas collection system power were cited as failures.

McMahon et al. (paper 14.05) described the performance of hillside fills. Both slopeside "wedge" fills and "canyon" fills (often from hilltop cuts) were examined. Three schools and over 1,000 residences were damaged by displacements of typically 8. cm. Damaged fills included older sites and one constructed only one month prior to the earthquake. Modern fills seemed to have been less prone to movement.

McMahon et al. resolved five potential mechanisms of deformation: 1. cyclic compaction; 2. "lurching" deformation; 3. differential dynamic response; 4. native ground failure; and, 5. localized sliding within the fill. These mechanisms occurred in combination. The first three causes were the most common, but the fourth feature appeared to have significant contribution. The authors recommend further evolution of practice standards to lessen fill deformation.

Lew et al. (paper 14.07) reported on temporary, shored, earth-retaining systems. Four locations of "temporary" excavation supports were evaluated. These systems normally include steel soldier beams backfilled with concrete in drilled holes. Tied-back anchors increase the shoring's horizontal resistance. Lagging is placed between the soldiers. Load tests are typically conducted on the anchors.

None of the retaining systems were found by *Lew et al.* to have significant movement horizontally or vertically in regular survey monitoring. The walls varied in height from 10 to 20 m. One system was two blocks from a free-field station that recorded a peak, horizontal acceleration of 0.88 g. The fourth shoring system had been abandoned for 11 years and showed no signs of distress after the earthquake.

Muraleetharan et al. (paper 14.11) authored a report on two Port of Los Angeles facilities: Berths 121-126 [berths] and Pier 300 [pier]. Both sites suffered lateral displacement and liquefaction of hydraulic fills with settlement. Simplified-SPT analyses to 2-D, fully coupled, effective-stress DYSAC2 procedures were used to investigate these locations. STABL 5M slope stability and Newmark Sliding Block analyses were conducted to determine the validity and accuracy of simplified procedures.

SPT-based liquefaction analyses predicted only marginal liquefaction at the berths and no liquefaction at the pier. 2-D DYSAC2 predicted movement observed in the field. Pseudo-static slope stability and Newmark's deformation analyses predicted the observed deformations well with average excess pore-pressures from DYSAC2. *Muraleetharan et al.* showed that liquefaction is more likely for only monotonically loaded areas than at dikes, which have cyclic loads imposed on monotonic burdens.

SEISMIC HAZARD

Hays reported on the recently appraised threat of blind-thrust faults in producing Los Angeles [LA] earthquakes. Present seismic design in the LA area may focus only on the San Andreas fault (1857 Fort Tejon M_s 8.25 Earthquake) and Newport-Inglewood fault (1933 Long Beach M_s 6.5 Earthquake). Blind-thrust faults are responsible for 1971 San Fernando M_s 6.5, 1987 Whittier-Narrows M_s 5.9, and 1994 Northridge M_s 6.8 Earthquakes.

Hays cited four LA, blind-thrust systems that could produced events. He questioned whether moderate events could be produced or if there exists the potential for large events on the "entire thrust fault system." The probability of large events on blind-thrusts is lower than the potential for the San Andreas, however the blind-thrust risk is much greater in the LA basin. Wide-spread high peak accelerations and long-duration pulses recognized by other session authors would be possible for a larger area, thrust fault break than the Northridge slip. *Hays* called for renewed study in regard to seismicity and the "complement" of this risk with existing earthquake preparedness scenarios.

GENERAL COMMENTS

The authors of Session XIV presented papers on the Northridge ground motion threat, project performance during the event, and the call of warning for blind-thrusts. Most papers provided real performance/analysis data as opposed to merely citing observations. Additional peer review of these types of papers stimulates the advance of design and practice.

Reporting of general design practice for designs subsequent to dynamic loading needs presentation for both failed and satisfactory structural performance. Conference and company, design peer review will aid the state of practice and individual designers. Designs of public structures should be available to the professional community.

Installation of strong-motion recorders will aid evaluation of coming events throughout our globe, but the subsurface conditions should be well investigated. Instruments should be collocated (preferably added, but possibly moved) at positions of known subsurface conditions.

The professional community should enhance its public involvement in seismic hazard mapping. The maps contained in *Chang et al.* (paper 14.10) and *McMahon et al.* (paper 14.05) should be added to preparedness and hazards maps. These authors are commended for their comparison of hazard to performance, evaluation of design standards, and recommendations for design improvements.